arose to offset the usual effects of low temperatures. On at least three different occasions rains and snows preceded the cold spells in the valley, and the condensation of a bountiful supply of aqueous vapor liberated enough latent heat to protect the crop.[3] In other instances a strong "canyon breeze" sprang up at the opportune time to mix the air and prevent much further cooling after dangerously low temperatures had been reached.

As an illustration of the narrow escape from total loss observe the following table showing minimum temperatures for March and April, 1921. After the 1st of May only one station reported a minimum temperature of 32° or below, and that station (Loma) was in the extreme lower end of the valley where little fruit is now grown.

Stations.	Lowest during month.			Stations.	Lowest during month.		
	March.	April.	May.		March.	April.	May.
	°	°	°		°	°	°
Clifton	....	23	37	Orchard Mesa	....	23	35
Fruita	19	17	34	Palisade	24	24	39
Fruitvale	20	25	35	Pomona	17	21	35
Hunter	18	21	36	Redlands	21	21	38
Loma	17	17	32	Grand Junction	23	28	38

The Smudging Committee's Report of 1912 sets the dangerous temperature lines for peaches as follows: Buds swelling, 15°; buds in the pink, 22°; full bloom, 29°; peach setting, 31°; dropping the shuck, 31°. For apples: Bud separating, 20°; bud in the pink, 25°; full bloom, 30°; fruit forming, 30°; petals dropping, 31°.

Since temperatures several degrees below these danger lines occurred during the period of development, it is remarkable that such an excellent crop of fruit is being harvested during the present season.

Other authorities[4] give somewhat lower critical temperatures than those above quoted, but there are so many factors aside from the actual temperature which enter into the freezing of fruit on trees that each locality is a problem in itself, and these values, arrived at through local study and experiment, perhaps apply best to the Grand Valley. For example, a temperature of 29° might seriously injure peaches when in full bloom in the arid climate of the Grand Valley and at an elevation of 4,600 feet, while at the lower elevation and in the more humid atmosphere of the Pacific coast the same fruit might withstand a temperature as low as 26°.[5]

When it was learned that, in several instances, severe freezes failed to materialize on account of an abundant supply of moisture in the orchards, a few growers experimented by spraying their trees with water instead of smudging on nights when freezing temperatures were indicated. The results were unsatisfactory, however, and later most of the fruit dropped from the trees which were sprayed. It was the intention to form a coating of ice around the fruit, thus holding its temperature at 32°, but failure was due, probably, to the fact that the experiment covered a too limited area, and the cooling effect of evaporation more than offset the warmth derived through freeing of latent heat in the process of ice formation. Moreover, ice can cool to below 32°, and if the fruit were not kept incased in ice throughout the entire period of low temperatures that night it was subject to more cold than would have been experienced under natural conditions.

[3] "Cold air prevents severe freeze." MO. WEATHER REV., April, 1921.
[4] *Farmers Bulletin No. 1096.*
[5] See Nichols, E. S.: Damage by frost in western Colorado, MO. WEATHER REV., April, 1913, p. 608.

A survey of the valley was made after the frost season of 1921, and it was learned that 29 growers in the vicinity of Palisade (representing a total of 200 acres) lighted their smudge-pots during the spring, acting upon advices sent out by the Weather Bureau office.

In the lower valley, where orchard heating has been discontinued, there seemed to be no further need for maintaining special meteorological stations, and therefore the special stations at Loma, Hunter, Pomona, Redlands, and Orchard Mesa, Colo., were closed on June 1, 1921. It is not thought that orchard heating will ever again be popular throughout the valley.

Over 900 carloads of Elberta peaches were harvested in the Grand Valley in 1921, and over 400 carloads of pears, notwithstanding the fact that the record of minimum temperatures which occurred during the season of blossoming would, at that time, have indicated a total loss.

In this connection it may be stated that it is highly probable that irrigation is playing an important part in making conditions better for fruit raising without artificial heating in the Grand Valley. Year after year since 1911 more land has been artificially watered. The relative humidity is thus increased over a large area, and this is favorable to the formation of local fog and clouds, and also to the liberation of considerable natural heat in the processes of condensation and frost formation. A map showing the Grand Valley appeared in the MONTHLY WEATHER REVIEW, for November, 1915, page 563.

DISCUSSION.

By E. S. NICHOLS, Meteorologist.

[Weather Bureau, San Jose, Calif., Sept. 24, 1921.]

Acting on suggestion by Mr. Hamrick, I am submitting the following remarks, not to controvert, but to supplement those made by him.

Even more than Mr. Hamrick does, I should emphasize economic conditions and results of experience in explaining the decline of orchard heating in the Grand Valley.

My first spring in the valley was that of 1911, at which time our fruit-frost service had been established only in a very informal manner. Orchard heating was at its height, though not by any means universal in the district. Unusually cold weather occurred during April; orchard temperatures as low as 15° and 16° were recorded in places on the 13th; and vigorous heating was practiced night after night.[6] Much fuel and labor was expended without evident adequate profit in the way of increased returns from the fruit crop, particularly in the apple districts. Consequently many growers in those districts failed to prepare to "smudge" during the season of 1912.

I thought that a revival of orchard heating would result from improvement in the Weather Bureau's forecasting and warning system and from better methods of heating and increase of knowledge regarding its results. In later years there were temporary revivals; but a combination of conditions prevented general resumption. For not only did the valley suffer from the general depression through which the fruit industry passed during several years, but, particularly in its lower sections, it had serious problems of its own. Also, experience has shown that, often a spring freeze kills only a portion of the fruit in an orchard,[7] and a full crop may be matured from a small percentage of the blossoms.

[6] See MO. WEATHER REV., Apr., 1911, 39:591.
[7] See MO. WEATHER REV., *Supplement No. 16*, p. 37, and Mr. Hamrick's report for 1921.

Thus the question of orchard heating became economic. Many fruit growers who believed in the operation in general were unable to raise money to buy fuel; while others found that heating did not pay under the conditions then existing in the valley. Thus, even before the World War many former "smudgers" had moved away or were compelled by force of circumstances to join the "slackers" referred to by Mr. Hamrick.

"Smudging" passed through two sudden declines; one immediately following 1911, the other due to effects of the war upon supply and prices of labor and fuel.

The above conditions were reported from time to time. Curtailment of the fruit-frost service was not recommended, however, because all of the substations were cooperative and their reports were gathered by telephone without additional expense. Valuable climatic data and experience, were secured by continuing the service intact. It is believed that all data and charts should be preserved for possible future use. All of the stations were found useful in connection with general crop reports and frost work, in both fall and spring.

It would seem that my article in SUPPLEMENT No. 16, MONTHLY WEATHER REVIEW, pages 38 to 45, should be mentioned in connection with description of charts and forecasting methods at Grand Junction.

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RESULTS OF EVAPORATION OBSERVATIONS.

[Submitted by Robert E. Horton, Voorheesville, N Y., Oct. 12, 1921.]

These records were established and maintained by the Bureau of Plant Industry of the United States Department of Agriculture. Through an agreement between the officials having charge of these records and the Chief of the United States Weather Bureau, they have been compiled by Robert E. Horton in the form in which they are here presented.

The accompanying Table 1 shows the locations of the stations, their approximate latitudes and elevations, periods covered by the records, which were generally kept from April to September of each year, and also diameters of the evaporation pans.

Initially, some of the pans were 8 feet in diameter, while others were 6 feet in diameter. In most instances the larger pans were changed to 6 feet diameter at the end of the first year. The dates of change, if any, are shown in columns (5) and (6) of Table 1.

The pans were galvanized iron, 24 inches deep, buried 20 inches in the soil and kept filled with water to soil surface level or 4 inches below rim of pan. While there appears to have been some variations, yet the intention and the general rule was to maintain anemometer cups 24 inches above rim of pan. Mean air temperatures were obtained by taking the average of maximum and minimum thermometers in standard shelters, the thermometers being about 4 feet above ground.

Humidity was obtained by means of sling psychrometers.

The instructions required that grass should be kept cut and other obstructions removed from the vicinity of the pans so as to permit free wind movement close to the water surface. At many stations records of water-surface temperature were kept. The mean was obtained by averaging the daily readings of maximum and minimum thermometers. The thermometer tube was removed from the metallic backing and the glass stem slipped through a cork sufficiently so as to float the thermometer with its bulb about one-fourth inch below water surface. In the accompanying tables, mean air temperature is designated θ_a; mean water-surface temperature, θ_w; wind velocity, in miles per hour, w; vapor pressure, in inches of mercury, v; observed evaporation, in inches per month, E_0. In order to afford a basis of comparing the measured evaporation with the causal factors, a few interpolations of some of these elements have been made. Interpolated figures are inclosed in parentheses. There have been no interpolations of evaporation amounts.

TABLE 1.—*United States Bureau of Plant Industry evaporation records.*

	Station.	Record years used.	Latitude (approximate).		Elevation above sea level	Diameter of pan	
						8-foot beginning.—	6-foot beginning.—
			°	'	*Feet.*		
1	Aberdeen, Idaho	1913-19	42	40	4,400	....	1913
2	Akron, Colo	1909-20	40	40	4,650	1909	1916
3	Amarillo, Tex	1908-19	35	20	3,676	1908	1910
4	Archer, Wyo	1914-20	41	00	6,012	....	1914
5	Ardmore, S. Dak	1913-20	43	20	3,557	....	1913
6	Biggs, Calif	1916-19	39	00	94	....	1916
7	Big Springs, Tex	1916-20	32	00	2,396	....	1916
8	Burns, Oreg	1914-19	43	40	4,125	....	1914
9	Chillicothe, Tex	1913-19	34	20	1,406	....	1913
10	Colby, Kans	1915-20	39	30	3,135	....	1915
11	Crowley, La	1910-19	30	15	21	....	1910
12	Dalhart, Tex	1908-20	36	20	4,000	1908	1917
13	Dickinson, N. Dak	1909-20	47	00	2,543	1909	1917
14	Edgeley, N. Dak	1908-20	46	20	1,468	1908	1917
15	Garden City, Kans	1908-20	38	00	2,836	1908	1917
16	Havre, Mont	1916-20	48	40	2,505	....	1916
17	Hays, Kans	1907-20	39	00	2,000	1908	1917
18	Hettinger, N. Dak	1911-20	46	00	2,253	....	1911
19	Lawton, Okla	1916-20	34	35	1,111	....	1916
20	Mandan, N. Dak	1914-20	47	00	1,750	....	1914
21	Moccasin, Mont	1909-20	47	15	4,228	....	1910
22	Moro, Oreg	1911-19	45	40	1,800	....	1911
23	Nephi, Utah	1908-19	39	45	6,000	1908	....
						(Pan-4 inches' diameter.)	
24	North Platte, Nebr	1907-20	41	20	2,841	1908	1915
25	Sheridan, Wyo	1917-20	44	40	3,790	....	1917
26	Tucumcari, N. Mex	1913-20	35	30	4,194	....	1913
27	Williston, N. Dak	1909-16; 1918	48	00	1,875	1910	....
28	Woodward, Okla	1914-20	36	30	1,900	....	1914

TABLE 2.

Month and year.	θ_a.	θ_w.	w.	v.	E_0.
Aberdeen, Idaho.					
1912.	°*F.*	°*F.*	*M. p. h.*		*Inches.*
June	63	64	8.4	....	11.737
July	66	67	7.3	....	12.882
August	63	61	7.0	....	7.255
September	57	(57)	7.9	....	5.337
Year	....	....	....	....	....
1913.					
April	46	....	7.4	....	5.396
May	55	56	7.4	....	6.926
June	61	64	5.2	....	6.163
July	65	67	5.1	....	7.316
August	69	67	4.7	....	8.178
September	56	56	5.1	....	5.653
Year	58.7	....	5.8	....	39.632
1914.					
April	45	....	6.9	....	4.190
May	53	....	6.2	....	6.853
June	58	....	5.3	....	5.677
July	70	....	4.4	....	8.084
August	67	....	4.9	....	9.268
September	56	....	4.6	....	4.443
Year	58.2	....	5.4	....	38.515